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DYNAMOS

AND

Electric Motors

AND ALL ABOUT THEM.

BY

EDWARD TREVERT, pseudon

ILLUSTRATED.

LYNN, MASS.:
Bubier Publishing Company.
1894.

Eng 4038.94.3

1894, Sept. 18.
Lawrence Scientific School.

98.9

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PREFACE.

In preparing this book I have selected such articles from reliable sources as I think would be of service for amateurs or students who are studying electricity, also, for those who contemplate building small machines, or desire to know how they are constructed.

I am indebted to Mr. A. E. Watson, A. B., for the chapter, "How to Construct a Dynamo," and to the Electrical World and Western Electrician for some valuable information used in this compilation.

EDWARD TREVERT.

Lynn, Mass., Feb. 1891.

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DYNAMOS AND ELECTRIC MOTORS.

CHAPTER I.

WHAT IS A DYNAMO? WHAT IS AN ELECTRIC MOTOR?

Do you know what a dynamo is? Do you know what an electric motor is? Should you ask most any person this question, they would immediately reply, Why certainly. But should you put the question, What is a dynamo? or what is an electric motor? nine out of ten of the same persons would not be able to answer you. Briefly speaking, a dynamo is a machine which converts mechanical energy into electricity or electrical energy. An electric motor is a machine which transforms electrical energy into mechanical energy or power. Broadly speaking an electric motor is simply a dynamo reversed, that is to say the motor is driven by electricity instead of being driven by mechanical means. But should we come down to fine points we would find that although dynamos and motors were identically the same in principle they differed very much in many details.

Practically a dynamo or an electric motor, electrically consists of three parts, the field, the armature and the commutator.

The field consists of magnets, which are iron cores solidly connected with an iron frame. Upon the magnets are wound layers of insulated wire. These magnets are called electro-magnets, as they become magnetic only when there is an electric current passing through their coils.

The armature may consist of a soft iron core mounted upon a shaft which revolves within the fields or it may be a stationary part around which the fields revolve. To the soft iron core of the armature a number of insulated copper wires are affixed with their ends connected to the segments of the commutator.

The commutator consists of a number of metal bars fixed radially around the shaft of the machine each bar being insulated from one another, and each bar obtains its electricity from the coil or coils attached to it. The commutator is employed to change the direction of the current generated.

There are two types of dynamos: the continuous current and the alternating current dynamo.

In the continuous current dynamo the current generated always flows in the same direction, there being a commutator from which the current is collected by the brushes.

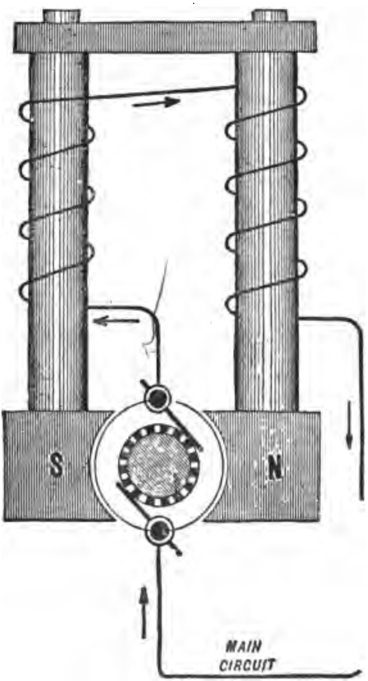
In the alternating current machine the current generated flows at rapid intervals, first in one and then in the opposite direction. This dynamo having no commutator, a collector of two metal rings is necessary on which the brushes rest. The magnets of this machine must have a continuous current to excite them, and this current is generated by another small, continuous current machine which is called the exciter.

There are three ways of winding a dynamo: the series, the shunt and the compound. In the series wound dynamo, the generated current is passed through the field magnet coils which are connected in series with the armature and external circuit.

In the shunt wound dynamo the field magnets are wound with fine wire to receive only a small portion of the whole current generated in the armature. These coils are connected to the brushes of the machine and constitute a by-pass circuit, or what is called a shunt.

The compound wound dynamo is a combination of the series and shunt. This dynamo is growing in favor, especially for incandescent lighting.

The reader may form a good idea of a dynamo by the accompanying diagram.



This figure represents a simple series wound dynamo and possesses but one circuit. To simplify the principle, in the illustration the winding of the field magnets is confined to a few turns, and by noticing the direction of the arrows you will see that there is a continuous current taken from the armature by the brushes and carried through the coils of the field magnets to the circuit. To produce a current a certain speed of the armature must be obtained, for the machine will refuse to magnetize its own magnets when there is too much resistance or too little speed.

The field winding of motors is adapted to the work which the motor is to perform.

For constant speed the shunt winding is used. Compound winding is theoretically more correct but a shunt winding will regulate the machine closely enough for all practical purposes, and is the one most commonly used.

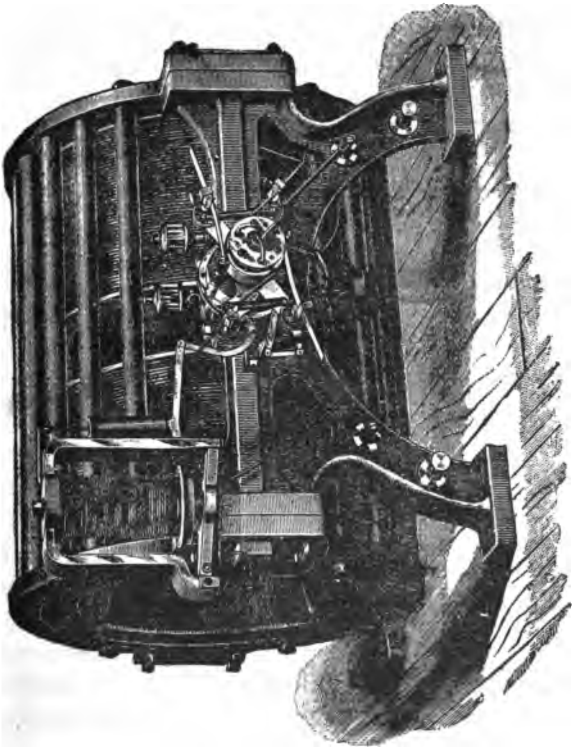
Series winding is used where a variable speed is required and where the regulation can be attended to by hand. Its chief advantage is in its great starting power.

CHAPTER II.

SOME DIFFERENT TYPES OF DYNAMOS.

THE THOMSON-HOUSTON ARC DYNAMO, illustrated on page 11, is remarkable for its construction. It was designed by Professors Elihu Thomson and Edwin J. Houston, of Philadelphia. Its armature is nearly spherical and is wound with only three coils. The three coils are wound over the shell of the armature in three sets of windings, each layer being insulated from the shell and its neighbors. When the winding is completed the three ends of the free coils are carried through an opening in the shaft and attached to the three segments of the commutator. The field magnets are cup shaped; they consist of two cast iron tubes, furnished at their inner ends with hollow cups cast in one with the tubes, and accurately turned to receive the armature.

Upon these tubes are wound the coils; afterwards the two magnets are united by means of a number of wrought iron bars which constitute the yoke of the magnet and at the same time protect the coils. The magnets are carried on a frame-work



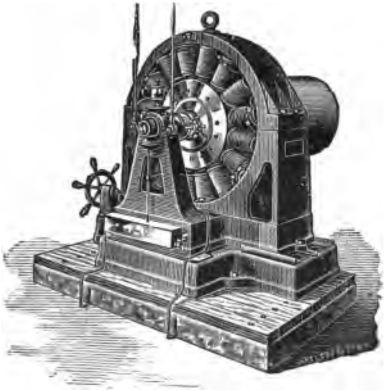
THOMSON-HOUSTON ARC DYNAMO

which also support the bearings for the armature shaft. Another remarkable feature of this machine is that its commutator has only three parts.

The largest machines have an electro-motive force of 3,000 volts, and will maintain 63 arc lights in a single circuit.

THE WESTINGHOUSE ALTERNATING CURRENT DYNAMO for generating the alternating current is represented by the accompanying illustration. It is apparent at a glance that it is very different in its principles and construction from the ordinary machine. In its mechanical and electrical details it represents a simplicity far greater than is possible with any dynamo for generating a direct current. The field is composed of a series of radial pole pieces having alternate polarity, the cores of which are cast solid with the base and cap respectively. The field coils are a series of bobbins each independent of all the others which are wound on shells, slipped over the pole pieces and held up by bolts at the periphery. These bobbins being supplied with a feeble current from the exciter are of course subject to no natural deterioration and are not liable to accident. They can only be damaged by extraneous careless ness, and, when such is the case, the cap of the dynamo is removed and any bobbin taken out and replaced in a few moments. The armature is removed in the same manner, as the whole structure of the dynamo, including the pole pieces and the bearings, parts along a horizontal plane through the shaft.

The engraving shows the side of the dynamo which carries the collecting ring; the other side has a similar bearing, beyond which is an over-hung pulley. This pulley is of compressed straw-board, which in experience is found to exceed all other material for belt traction. The dynamo rests upon a cast-iron base and is adjustable by means of a belt tightener. The dynamo can run in either



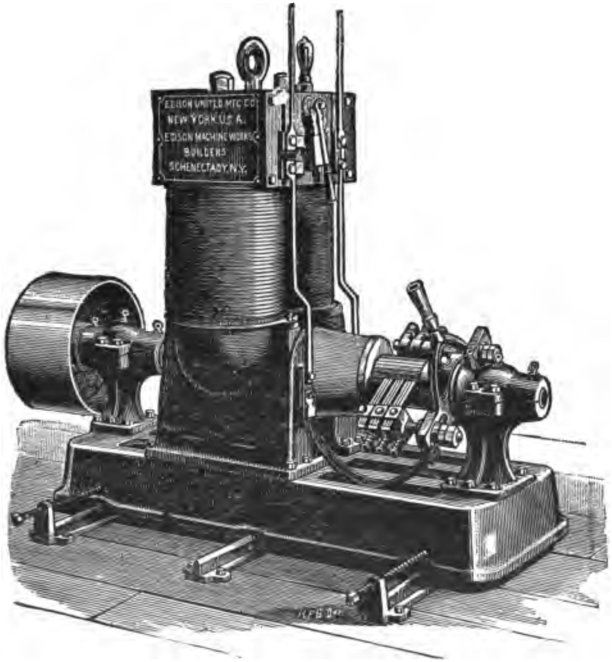
The Westinghouse Alternating Current Dynamo.

direction and stand either way around on the base. This of course adapts it universally to any situation.

The armature is a structure of great directness and simplicity. The body of the armature is of laminated iron plates freely perforated for ventilating purposes. A single layer of wire is wound in flat coils back and forth across the face of the armature in a direction parallel to the shaft, being retained by stops on the ends of the armature. Mica and other adequate insulation is provided and the whole is wrapped with binding wire. A ventilator is attached to each end of the armature and draws a strong current of air through it.

The observer will be struck by the simplicity of the winding on an alternating current armature as compared with that necessary in the direct current machines. The total weight of copper on a 750-light armature is 16 lbs., disposed in a single layer, which being on the surface is readily kept cool, and which can be inspected for deterioration or flaws of any character. A direct current armature of type most generally in use of 750 lights capacity on the other hand carries more than 10 times this amount of wire.

THE EDISON DIRECT CURRENT DYNAMO.—The field magnets consist of vertical cylinders with large wrought iron cores, which rest upon cast-iron pole pieces, and nearly enclose the armature. The armature is drum shaped. The core consists of a number of sheet iron discs insulated from each other by sheets of thin paper. The core is mounted on an iron shaft but insulated from it by an interior cylinder of lignum vitæ, while an external covering of paper insulates it from the coils. The coils consist of cotton covered copper wire, stretched longitudinally and grouped together in parallel, a number of wires in a group, all of the group being so connected as to form a continuous closed circuit. The groups are arranged in concentric layers, and are of the same number as the segments of the commutator, the ends of the wires in each group being attached to arms connecting with the commutator segments, a spiral arrangement being adopted in making the connections between the straight portions of the wire and the arms. The object of grouping is to secure flexibility for winding by the use of small wire and low electrical resistance by having several wires in parallel, the effect as to the resistance being practically the same as if the several wires were combined in one. At the ends the wires are insulated from the core by discs of vulcanized fibre with projecting teeth. The discs of the core are bolted to-



EDISON DIRECT CURRENT DYNAMO.

gether by insulated rods, and the coils are confined by brass bands surrounding the armature. The brushes are composed of several layers of copper wires combined with flat copper strips, two layers of wire being placed between each two strips. This arrangement is to give a more perfect connection, and to prevent sparking by furnishing numerous points of contact, the copper strips confining the wire and making the brush more compact. On page 16 will be found an engraving of the machine.

CHAPTER III.

HOW TO CONSTRUCT A DYNAMO.

As compared with many mechanical inventions the electric generator or "dynamo" is of simple construction. There is but one moving part, yet the hardships to which a dynamo is subjected forbid any negligence of workmanship.

The revolving part, usually the armature, is heavy and moves at high speed, hence it must be perfectly balanced, and held stiffly in easy running bearings. A most important consideration is to have the machine of such construction that the armature may be easily removed and replaced without injury.

Figure 1 on the following page represents a dynamo of familiar construction of the Edison general appearance. It is two-horse power capacity, capable of supplying twenty 16 candle power incandescent lamps, or two arc lamps of 2000 candle power each. Running as a motor it would supply about 1½ horse power. The parts of a dynamo may be divided into three classes:—1st, the purely stationary; 2d, the revolving; 3d, the

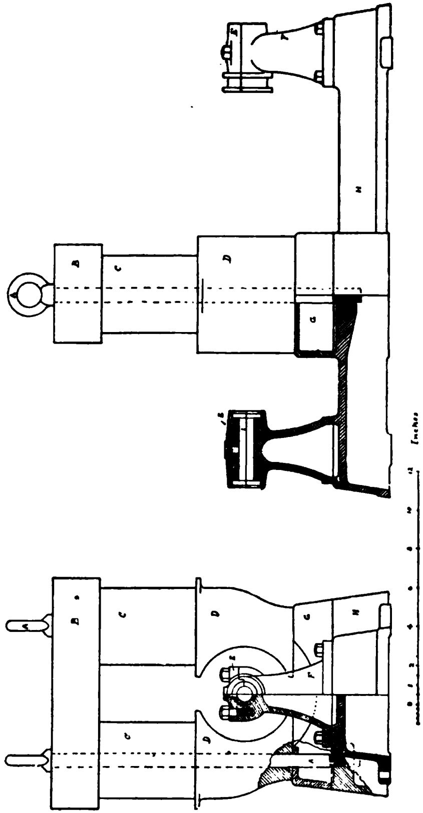


FIGURE 1.

"trimmings," which serve to connect the first and second. This article as has been noted will consider the first class.

To generate electricity there must be a magnetic "field of force" to act on the armature. This magnetism is made to appear in two heavy cast-iron "pole pieces" D. D.; they receive their magnetism from the wrought iron "cores" C. C., over which the spools of wire are to be slipped. The cores are joined at their upper ends by the wrought iron block B. Unless due precaution is taken the magnetism in the pole pieces would wander through the iron base of the machine, instead of confining its attention to the armature; a hollow casting of brass or zinc separates the pole pieces from the base. The base is of cast-iron and carries also the standards for the shaft bearings. Two long lifting bolts A. A., reach entirely through the magnets and the "grid" C., and screw into the base; unscrewing these and removing the loosened parts the armature lies open to the easiest access.

The cast-iron standards F. F. are, in shape, hollow circular columns mounted on rectangular pedestals; in the four corners of these are the bolts. Of the standards one is further removed from the pole pieces than the other in order to give room for the commutator; it also has a groove turned in its inner rim to hold the movable arm that carries the brushes. The standards are provided with gun metal linings for the shaft bearings. A chamber in each end catches the waste oil and holes conduct the oil to the interior of the standards where it can be drawn off.

Provided with the castings and other material how should an amateur mechanic put the dynamo together?

Plane the bottom of the base where it is to touch the floor and drill the holes in the four projections; then plane the upper surface in the three places where parts are mounted. Screw the standards in position, as nearly as can be estimated. Now true out the holes in their upper ends, between lathe centers, unless a boring hole is convenient. Plane the grid, top and bottom, and secure it in position with two dowel pins, and a few temporary bolts. Plane the pole pieces, top and bottom, and bore the bolt holes through. Adjust them in position on the grid so that their center will correspond with the center line of the standards; mark the position for the bolt holes in the grid. Now drill through the latter, and tap out the holes in the base; put two dowel pins between each pole piece and the grid, so that there may be no skewing.

The cores should be fairly smooth and have the ends square; for this purpose the bolt holes had better be drilled first and the cores turned on an arbor. The magnetic yoke B need be planed on its lower surface only. Drill the holes through this and the parts are ready to be bolted together. Get a boring bar that fits in the holes in the standards and bore out the pole pieces to the right diameter 5°. The boring need not be very smooth, only the armature as it revolves should have equal clearance everywhere.

The linings or bearings should be made in halves so as to take up the wear, and allow easy scraping and cleaning. Nipples in the upper halves enter the oil cup holes in the caps to prevent the linings from turning; shoulders at the ends prevent longitudinal motion.

When all this has been done the builder is ready, if his courage is good, to undertake the armature and commutator.

ROTATING PARTS.—To build a reliable and efficient dynamo is no amateur's play. The construction of the parts described in the previous article will require good tools and some familiarity with their use. In the armature and commutator the builder will find good tests of his mechanical skill.

The revolving parts of a dynamo consist of shaft, armature, commutator and pulley, which are shown in figure 2, on page 24.

Good machine steel should be used for the shaft *A*, and it must be smooth and straight. To prevent springing, and afford ease in putting the armature together, the diameter in the center is $1\frac{1}{16}$ inches. This portion is 6 inches long and has threads, 16 to the inch, cut half an inch up at each end. Extending from the threaded portion to the bearing size, the shaft is $\frac{15}{16}$ of an inch, at the bearings $\frac{3}{4}$ of an inch, and for the pulley $\frac{11}{16}$ of an inch. The shoulders at the beginning of the bearings serve to keep the armature between the pole pieces, about $\frac{1}{8}$ of an inch end-play will be useful to give the armature a little liberty, and allow the commutator to wear smoothly.

Wrought iron boiler plate $\frac{1}{2}$ of an inch in thickness, will do for the armature heads "*B B*." They should be chucked in a lathe and turned on one face, the hole drilled and threaded to fit the shaft. For turning the other side and getting to right diameter, it will be best to screw them on a short stiff arbor—this arbor will be necessary for the next operation; 32 slots $\frac{1}{16}$ of an inch wide and $\frac{1}{2}$ inch deep are to be cut in the rim of the heads. This should be done in a milling machine.

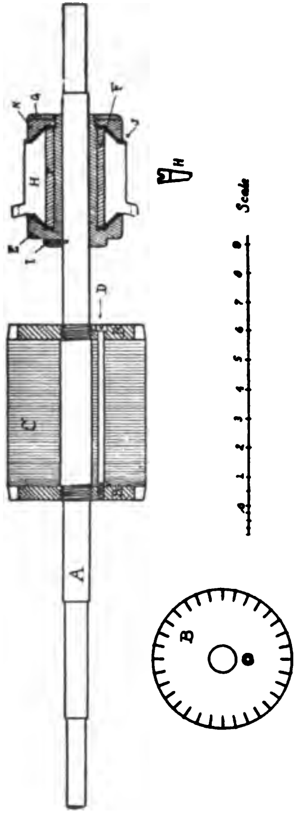


FIGURE 2.

These slots are to receive pegs that keep in position the copper wire with which the armature is wound.

The center, "*C*" of an armature called the core is not of solid iron, as the rapid magnetization and demagnetization would heat a solid mass sufficient to burn the insulation of the wire. Sheets of the softest iron, about $\frac{1}{100}$ of an inch thick separated by tissue paper are used. For this machine the sheets should be about $4\frac{1}{2}$ inches in diameter with a $1\frac{1}{16}$ hole in center.

Screw one of the heads very tightly on the shaft and lay on a sheet of paper, then a sheet of iron, another of paper, and so on until the right amount is built up. It will require a few trials to determine just the number of sheets necessary.

Screw on the other head as tightly as possible and see that the whole length is just right—6 inches—the same as the width of the pole pieces. Holes may be drilled in the heads to admit the use of spanner wrenches for tightening. A $\frac{3}{8}$ of an inch bolt covered with paper, except at the threaded portion, inserted through a $\frac{7}{16}$ in. drilled hole, must be put in the core, as shown, to bind the whole together. With this precaution the sheets cannot slip nor the heads unscrew. The armature is now to be put in a lathe, and with suitable steady rests to prevent springing the shaft, turned smoothly to its correct diameter, $4\frac{3}{8}$ inches, the heads beveled and corners rounded.

There are several ways to make a good commutator, but any one of them requires time and care. It is the only part of a dynamo that receives serious wear; besides a poorly made commutator will spark so as to work its own destruction.

Get a casting of as nearly pure copper as possible and turn it to the shape shown in section at *H*. Mount it on an arbor in a milling machine, and saw it with a cutter $\frac{1}{16}$ of an inch thick, almost through, into 32 sections. Intermediate slots $\frac{3}{16}$ of an inch deep, $\frac{1}{16}$ of an inch wide, in the flange portion will make allowance for connecting the wires with which the armature is to be wound. Fit mica to each of the dividing cuts and make the pieces of the same shape as the commutator segment. Washers "*J J*" of vulcanized fibre are turned to conform to the shape of the brass shell *E* and copper segments *H*. The ring *K* is of the same shape as the head of the shell *E*, and is to be forced up by the nut "*G*." With a hack saw separate the segments *H* entirely, and file off the burr from each. These with the mica between can be set up to form a cylinder around the fibre bushing *F*. It will be well to make the outside diameter of this bushing about $\frac{1}{32}$ of an inch less than was the hole in the copper body of the commutator so that when the shell and ring are put in place and the nut screwed up, the mica may be tightly pressed between the segments. After the outside has been turned and smoothed with fine sandpaper the commutator will be ready to put on the shaft. For securing it in position a set screw may be used, the blank end of which enters the shaft 1/8 of an inch.

The pulley is of no special construction. An ordinary iron one will do, but a paper or wooden face will have its advantages: 4 inches in diameter and 3 inches face will be sufficient. Set screws butting on the shaft are permissible in a small machine like this, but it will be better if they rest upon a key.

Last of all for this stage of the work, the armature should be set upon horizontal ways and balanced. This can easily be accomplished by drilling 1/4 inch holes through the heads on the heavy side.

TRIMMINGS.—By the trimmings of a dynamo the reader is not to understand that these parts are for ornament only. In fact they are essential, as they serve to connect the revolving with the stationary parts, to connect the dynamo with the circuit it is intended to operate, and to provide means for regulating the action of the machine.

Like the main part of the dynamo these accessory parts may be any one of a variety of forms. These are shown in figures 3 and 4.

The "brushes" are a very important part of a

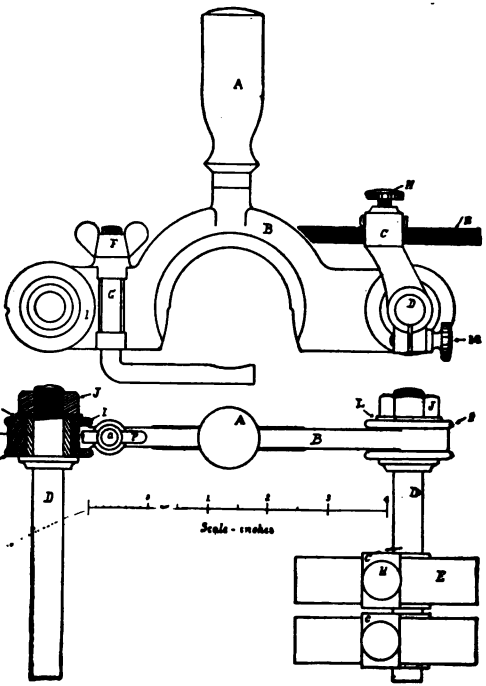


FIGURE 3.

dynamo; they should be very springy, yet bear firmly on the commutator. Those shown here at *EE*, are two of the set of four to be used. They consist of a large number of leaf copper ribbons laid one on another and soldered at one end. The other end is beveled to fit the commutator. Two independent brushes are used on each side so that one may be removed and repaired or adjusted without stopping the dynamo.

The brush holders *CC* are of brass castings. Through one end of each a slot $\frac{3}{16}$ by $\frac{3}{8}$ admits the $\frac{3}{4}$ x $\frac{1}{4}$ brush; a suitable thumb screw and jam plate holds the brush securely in position. The opposite end of the holder is sawed through to a half inch hole and pinched by a thumb screw *M* against the brass spindle *D*. Hard rubber washers and bushings clearly shown in the figure insulate the spindles from their holder *B*, called the yoke.

The position of the brushes on the commutator must be adjustable; for this purpose the yoke has its center bored out to fit the groove turned on the inner rim of one of the bearings described in the first article. To prevent undue moving a clamp consisting of a bent rod *G* tightened by the thumb nut *F* binds against the lower part of the groove. There will be sufficient elasticity in the rod to allow the rod to be moved when desired without

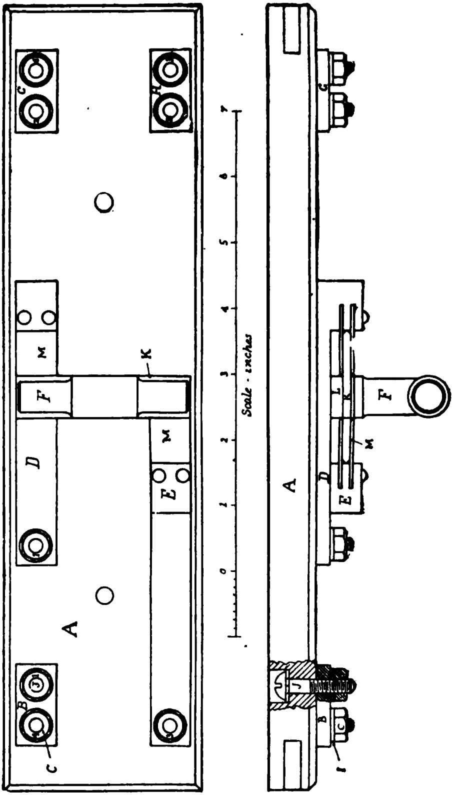


FIGURE 4.

loosening the nut, yet the vibration or jarring of the machine will be insufficient to alter the position after once being set.

At *L* washers are shown to receive the direct action of the nuts, but they also serve to attach the flexible cables that conduct the current. One side, not shown, should be extended into a tang about half an inch wide; this can be curled so as to allow the cables to enter and be soldered in.

The cables lead to the connection board. This switch or connection board will vary according to the purpose for which the machine is built. Shunt, series or compound winding of the wires of the dynamo or motor will alter the connections. The one shown is for a shunt dynamo, and is of such construction as to be readily adapted to other conditions. A maple board forms the base. As it fits on the commutator side of the magnetic yoke of the dynamo, it must be of the same size—3x12. The switch in the center consists of a sheet brass blade *K*, $\frac{1}{8}$ of an inch thick; at each end is a right angled projection that enters between the brass contacts *M*, held in brass blocks *E* and *D*. The surfaces of each must be scraped or filed to make uniform contact. The builder may use his own ingenuity in getting the switch blade pivoted. One way is suggested. A stud *I* is held rigidly in the board by a countersunk nut, the blade *K* attached to the hard rubber handle *F*, on this. A pin through *F*, and through an elongated hole in the stud will limit the amount to which the switch may be opened, yet keep the blade in the right position to enter the contacts *M*.

Contact blocks *B*, *C* and *H* are also of brass held on the board by screws *J* as shown. The holes in the back of the board should be filled with resin or shellac. Wires for connections are to be held under the washers and nuts.

The conventional form of binding posts seen on bells and telegraph instruments are not suitable for a dynamo. Besides offering insufficient surface, thumb shrews easily rattle loose. Safety fuses are desirable in this machine, and places are provided for two, one on each side of the circuit. The current should pass from one set of brush holders by a flexible cable to the clamp 3 on *E*; through the switch blade to 1 on *D*, through a fuse to 1 on *B*; thence from 4 to the lamps, or whatever the dynamo supplies; back to 4 on *C*, to 2, through a fuse to 2 on *H*, and by a flexible cable from 3 on *H* to the brush holders on the opposite side of the commutator.

No description has yet been given for the field spools. These are very simple, consisting of $\frac{1}{8}$

brass flanges or rings united by tin cylinders. Allowance should be made for winding wire 1 inch deep radially. The spools should slip easily over the cores and be short enough to allow the magnetic yoke to rest evenly on the cores.

Thus far the builder has done a large amount of work, but the whereabouts of the electricity, for which the dynamo is intended, remains unseen.

Let us suppose that the builder wishes to supply 20 incandescent lamps. These may be conveniently 75-volt lamps. The armature should then be "wound" with No. 15 (B. & S. gauge) double cotton-covered copper wire—8 pounds will be sufficient. Insulate the core thoroughly with paper and shellac, $\frac{1}{16}$-in. thick in all. Cut through into the slots in the heads and drive in the 32 leatheroid pegs in each. To show these on a larger scale the armature is represented as having only 8 pegs. (See Figure 5.)

The winding can be conveniently done in a lathe. Leave an end of 6 or 8 inches at the commutator side and pass the wire between any two pegs, then parallel with the shaft, between corresponding pegs in the other head, across the end, back between pegs diametrically opposite to the starting point. Continue the wire alongside the first turn until the whole space is filled. Six turns will do this. Do not cut the wire, but make a loop of 4 or 6 inches and wind the space between the next pegs likewise, make a second loop and wind the third space and so on until the whole surface of the core is covered with one layer of wire. This will give 16 loops for connecting with the commutator. Thirty-two loops, however, are needed. Continue a second layer on top of the first between the same pegs. When this is done join the end with the beginning and the 32 loops are ready to be soldered into the slots in the commutator ears. Do not connect these straight, but

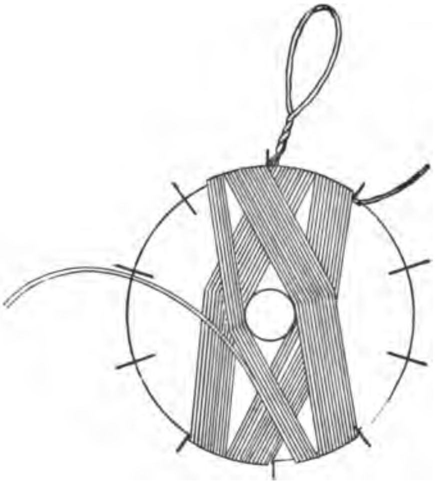
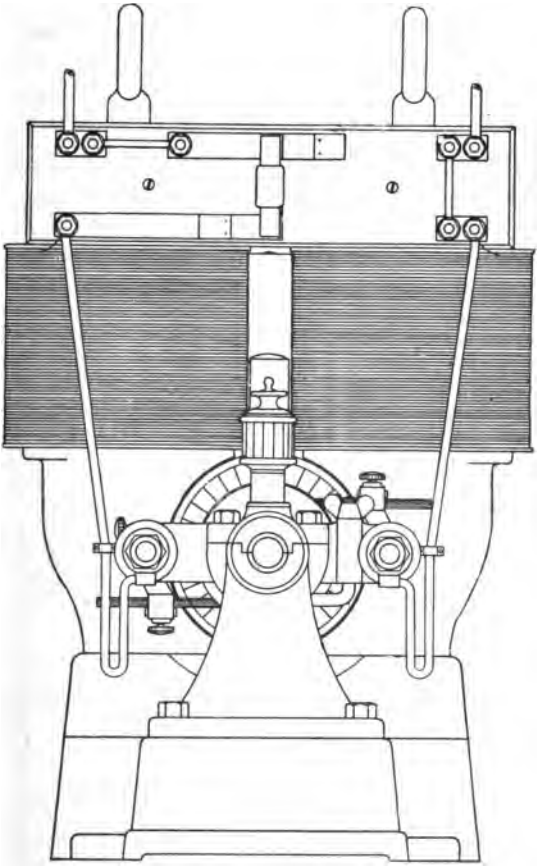


FIGURE 5.



END VIEW OF DYNAMO.

give them a "lead," so that when running, the brushes may be in a convenient horizontal position. Connect a loop with the fourth segment away from the nearest one and let the other loops follow in the same order.

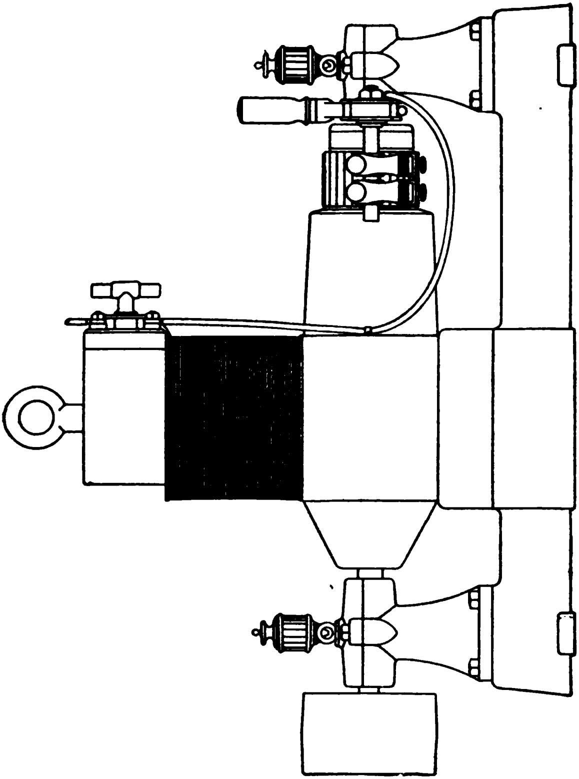
Upon paper strips in four equally distant places wind tightly wrapping wires of fine brass. This will keep the copper wire in place.

Usually a hood of canvas is put over the ends of the armature to give a neat appearance.

Insulate the spools like the armature and wind 10 pounds of No. 23 wire on each and connect the two spools in series.

At 2,200 revolutions per minute this machine should give a current of 80 volts and has a capacity of 15 ampéres.

The exact winding of a dynamo depends on such a variety of considerations that for a particular case the builder is advised to consult an electrician, but the winding here indicated will be easy and the machine will supply a current of convenient strength for a large variety of experiments.



SIDE VIEW OF DYNAMO.

CHAPTER IV.

SOME DIFFERENT TYPES OF ELECTRIC MOTORS.

There are a great many types of Electric Motors. Among the most prominent are the following:

THE FORD & WASHBURN ELECTRIC MOTOR.—One of the growing electrical companies of Cleveland, that has made a sudden and strong pull for popularity during the past year, is the Ford & Washburn Electric Co. Having a good thing in their improved armatures for dynamos, they propose to push it for all it is worth. The claims made for this improvement are strong and, being backed up by work for some of the leading establishments of Northern Ohio, they appear to be well founded. The special improvement, which, they claim, puts their dynamo far in advance of all others and places the use of electricity for lighting within the reach of the smallest plants, is its self-ventilating feature; but the motor itself possesses many points of superiority, attention to a few of which is herewith briefly directed.

The bed plates and brackets are one complete casting. The magnet yokes are wrought iron

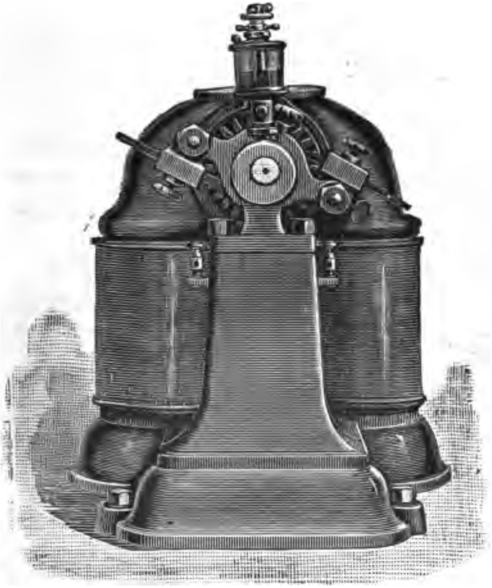


Figure 1.

THE FORD & WASHBURN ELECTRIC MOTOR.

fastened to the bed plate, and the pole pieces are separate castings bolted to magnet yokes. The field cores are wound on separate shells, and are interchangeable for all machines of same size. The armature shaft is steel and of extra large size. The especial feature of their dynamo, as above stated, is the armature, which is self-ventilating.

It draws a current of air from both ends and along the line of shaft and out through the discs, which are separated, and through the winding, with openings to let the air pass out. The rapid rotary motion of the armature sends out the current of air, which keeps the armature and pole pieces cool and therefore more effective than the old style which is so liable to heat up. This self-ventilating feature it is claimed, is found in no other dynamo at present manufactured. It is adapted to both motors and dynamos. Fig. 1 shows the motor, Fig. 2 the armature, the arrows indicating the direction of the current. These dynamos are of high efficiency, and are rapidly being introduced into industrial establishments.

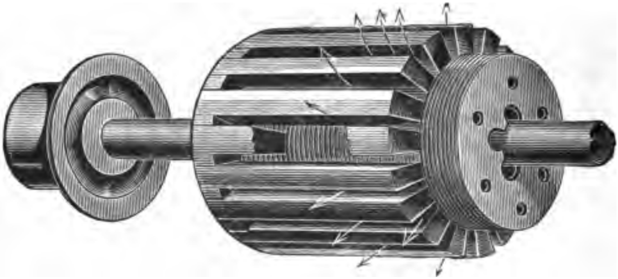


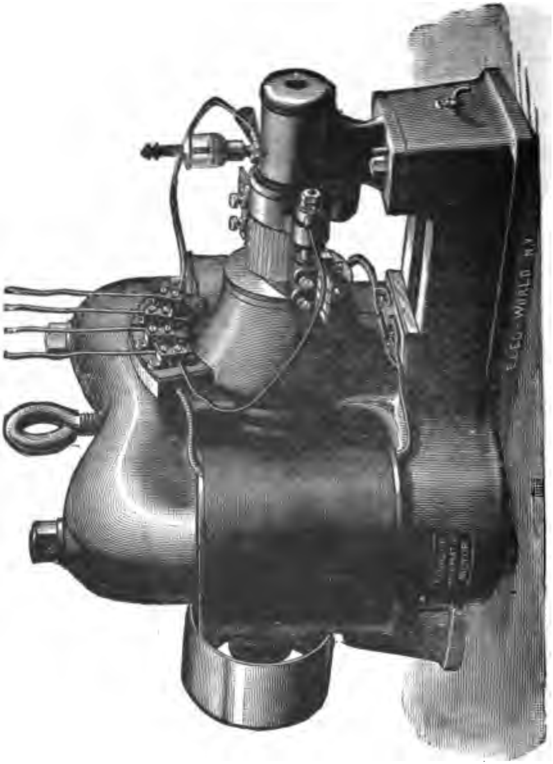
FIGURE 2.—ARMATURE.

THE SPRAGUE MOTOR. For stationary work, constant speed is attained by a special patented method of winding the magnetic-fields by means of which the speed of the armature never varies, whether working under full or no load.

It is a well-known fact that the ordinary shunt-wound electric-motor, when running on a constant potential circuit, will vary the speed somewhat with the load. The field, being excited independently of the armature, is constant and since the load varies with the motor electro-motive force and the field is constant, it follows that the speed must also vary with the motor-electro force. The torque is proportional to the current in the armature, and the speed will be slowest with the greatest load, and fastest with the lighest.

Mr. Sprague's method of keeping the speed constant consists of compounding the field-winding by placing next to the shunt-coil a short demagnetizing coil in series with the armature. By means of this coil, the magnetism of the field is varied whenever the load varies, so that the speed is maintained perfectly constant by means of an inverse varying of the strength of the field-magnets.

The motor is also non-sparking, due to the neutral point being held fixed under the brushes, and not changing from variations in load.

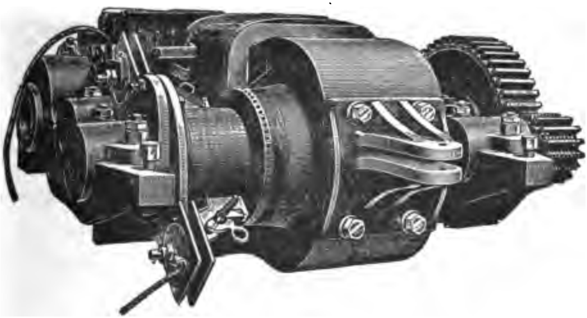

ELEC-WORLD N.Y.

THE SPRAGUE STATIONARY MOTOR.

The Thomson-Houston Railway Motor is noted for its neatness of design, compactness and reliability.

It is substantial, well built, and will stand severe strains to the mechanical and electrical parts, without injury.

The fields are made rectangular in section, of the best wrought-iron, and on these are slipped the coils of copper wire, which are wound upon iron bobbins or spools.



THOMSON–HOUSTON RAILWAY MOTOR.

To avoid loss by Foucault currents, the armature is built up of thin plates of soft iron, with thin paper between the laminations; the winding is a modification of the Siemens' type.

The commutators are of the purest copper, and are held together by a gun-metal shell.

All wires and all parts of the motor are *water-proof;* whole bucketfuls of water have been repeatedly poured on these machines without the slightest damage.

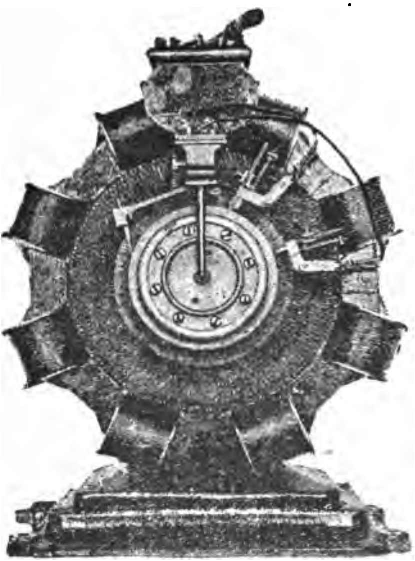
The gears of the motor are made up of raw-hide and steel, as by this combination the noise is reduced to a minimum.

A strong magnetic field is used, so that there is little change in the line of commutation, and the position of the brushes is never changed either for varying loads or reversal of direction.

The speed is controlled by a novel rheostat, made up of sheet iron and mica.

The cars are ordinarily equipped with two motors giving ten or fifteen horse-power each, capable of running with a full load at the rate of fifteen to twenty miles per hour.

THE NEW BAXTER MULTIPOLAR STATIONARY MOTOR.—This motor, which we illustrate herewith is the latest machine brought out by the Baxter Motor Company. It is designed for slow speed, and will run at velocities ranging from 900 for the smallest sizes to about 400 for the largest. It is an eight-pole machine, the field being built up of eight magnets, forming consequent poles. The magnet cores are laminated, and are clamped together so as to form a rigid ring, almost as much so as if they were made of one solid piece. This field ring is secured to the frame of the machine by four stout bolts attached to the poles of similar sign. The armature is a tooth "Gramme" ring and the total air space is very small, being but a small fraction of an inch. The magnetizing force



The New Baxter Multipolar Stationary Motor.

required to saturate the field in the 10 h.p. motors is less than 4,500 ampère turns. The shaft runs in two large bearings in the centre; the driving pulley is placed at one end, while the armature is at the other. The bearings are both in one solid frame, so that it is impossible for them to get out of line; the shaft is made of sufficient size to prevent springing and the machine is said to run without any tendency whatever to develope heat in the bearings. By this construction the machine can be easily taken apart. All that is necessary is to take off the pulley and the brush holders, then the armature and shaft can be removed at once.

The Baxter Company expects to make this type of machine in all sizes from three horse power up, and the same design with the addition of an outside bearing for the pulley end on the shaft will be used in the company's large generators for railway work. Several small motors of 10 h.p. and under and generators of 75, 100 and 125 h.p., intended for railway work, are now under way. These generators will either be compound wound or separately excited. The Baxter Company advocates the separate exciter, where it is desired to obtain the very best results. Although the speed at which the machines run is very low, their efficiency is said to be very high, and the output per pound of weight is, as might be expected, greater than can be obtained with the ordinary two-pole machines.

It is stated that the company's eight h.p. 500 volt machines, which revolve at 800 revolutions per minute, will weigh complete a little over 500 pounds, and the electrical efficiency will be over 95 per cent. The 75 h.p. generator, which runs at 500 revolutions per minute, will have an electrical efficiency of over 96 per cent., and will weigh about 6,000 pounds. This generator has an armature 24 inches in diameter with a 9-inch face, and will be driven by a 14-inch double belt. The shaft will be 4½ inches in diameter and of hardened steel.

The perfection in the design of the present machines, which is well exhibited by the illustration, shows that he has given the matter careful attention, and is determined that his company shall keep among the foremost establishments in the electrical field.

THE PERRET MOTOR.—The chief distinctive feature of the Perret machines is the lamination of the field magnet. Instead of casting or forging this in several solid pieces, as is usually done, they build it out of thin plates of softest iron, which are stamped directly to their finished form and clamped together by bolts in such a manner as to secure great mechanical strength.

The advantages of such a construction have long been recognized by electricians, and are, in brief, a magnetic field of much greater intensity than can be obtained otherwise, and the entire prevention of all wasteful induced currents in magnets and pole pieces—features of the greatest importance. The only disadvantage has been the greater cost as compared with solid magnets. This, however, we are able, by our inventions and by improved methods, to largely overcome.

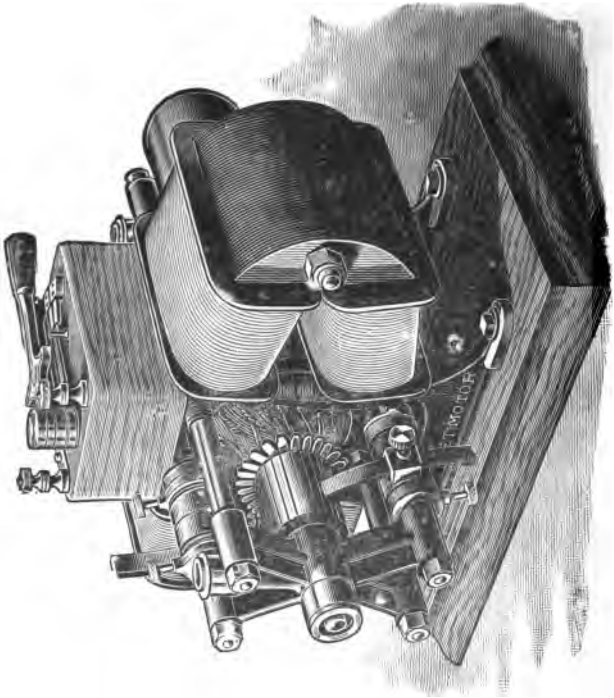
The armature core is also laminated, and the plates have teeth, which form longitudinal channels on its periphery in which the coils are wound.

The plates in both field and armature are in the same plane, and are of softest iron, with its grain running in the direction of the line of magnetic force, and there is the least possible break in the continuity of the circuit, there being no air gap between the iron of the field and the iron teeth of armature except that required for clearance in rotation. Thus we have a magnetic circuit of lowest possible resistance, and it follows from well known laws that we secure the maximum of effective magnetism with a minimum expenditure of magnetizing power. The armature coils being practically imbedded in the armature, receive the highest inductive effect from the intensely magnetized iron.

The high efficiency which such construction should give theoretically is practically demonstrated by the machines in actual work, and ranges from 70 per cent. in the smaller to 93 per cent. in the larger.

Attempts have been made by many since the days of Pacinotti to use toothed armatures, but with the result that very troublesome and wasteful heating effects were produced in the solid magnets and pole pieces commonly used. With our laminated field magnets these disadvantages are avoided and we are able to secure the advantages enumerated as well as others, among which may be mentioned the important ones, positive driving of the armature coils and less liability of winding out of balance.

The speed is a most important point for considerations. It is well known that most machines must be run at very high speed to secure reasonable efficiency and output without excessive bulk, weight and cost. In the opinion of many of those best competent to judge, this is their most serious defect involving frequent trouble, rapid deterioration and the employment of expensive and wasteful



THE PERRET ELECTRIC MOTOR.

gearing. In the Perret machines this is entirely avoided. Type D machines, for instance, are run at less than half the speed of other machines of equal power, weight and cost. This great improvement removes the last objection to electrical generators and motors.

It should be noted that, as a rule, reducing the speed of a given machine reduces the power or output correspondingly, and increasing the speed, increases it. For example, Type D 1 motor, running at 600 revolutions per minute, develops 4 H. P. If we were to wind it for a speed of 1200 revolutions per minute (which is lower than the average of others), it would be easily 8 H. P.

The regulation is entirely automatic. Perret motors run at practically constant speed, regardless of changes in load. The regulation of dynamos is equally as good. For instance, the one-half horse power machine will drop in electro-motive force when run as a dynamo, and vary in speed when run as a motor less than 5 per cent. between no load and full load. This is quite remarkable, but the larger machines are still better.

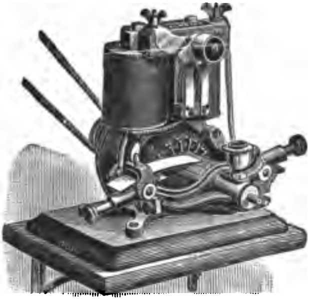
This superior regulation is due to the fact not always given its full weight, that the regulation of a shunt-wound machine depends not only on the internal resistance of the armature coils, but also to an eqaul, if not larger degree, on the intensity of the field. In other words, the lower the internal resistance of the armature coils and the lower the resistance of the magnetic circuit, the closer the regulation.

The practical advantages of low speed machines are many. For instance in ordinary machine shops, wood-work shops, printing offices, etc., the shaft is commonly run 200 to 300 revolutions per minute and it is a simple matter to belt direct to it from a motor running 500 to 600 revolutions, thus saving the first cost of a counter-shaft and one belt and saving also considerable power which would be lost in transmitting through the counter-shaft and additional belt which would be used necessarily with a motor of high speed. The advantage is equally as great in case of elevators operated by a belt from the motor, and indeed, it is possible to gear direct from the motor to the elevator.

THE C. & C. ELECTRIC MOTOR.—*No. 1, Type A.*—For use with *any battery* (such as a bi-chromate of potash battery) giving a very large current. The ordinary telegraph or telephone battery cannot be used for this purpose. This Motor was specially designed for running ordinary family sewing machines, but is equally well adapted to running dental drills, fans, jig-saws, and to all other purposes requiring about the same amount of power.

The form of the Motor is shown in the accompanying cut. Its character and capacity are as follows:

Weight, 13 pounds. Size, $7\frac{1}{2}$ x 5 x 3 inches. Resistance, $\frac{1}{7}$ Ohm. Capacity, up to $\frac{1}{8}$ horse power, according to the current supplied. Current capacity, 20 ampères. Speed from 500 to 2,000 turns per minute, according to power required. Speed required for running average sewing machine with the "C. & C." battery, 1,200 turns per minute. No sparking at commutator, the armature having continuous winding.


THE C. & C. ELECTRIC MOTOR.

Electro-motive force required to run Motor, from 3 to 9 volts, according to power required. For average sewing machines from 3 to 4 volts. Counter electro-motive force generated by Motor running at 1,500 turns per minute, with 18 ampères in field, 5 volts.

CHAPTER V.

HOW TO BUILD AN ELECTRIC MOTOR.

The fields of this machine are to be made of 5-in. wrought iron pipe. Get as thick a piece as you can, ½-in. is about the thickest regular size but sometimes odd sizes can be found which are larger. It should be four inches long. From a piece of 4-in. pipe, ½-in. thick and four inches long, cut two-quarter segments and screw them opposite each other to the inside of the first piece of pipe.

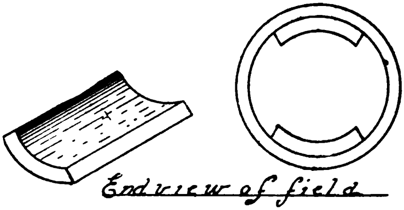
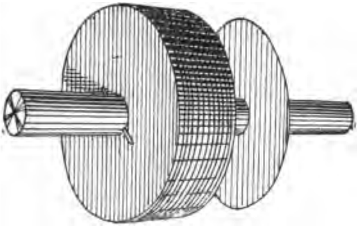


FIGURE 1.

The inside of the pipe where the pieces come and the convex sides of the pieces ought to be filed so as to make as perfect a fit as possible between them, carefully insulate the space between the pole pieces with several thicknesses of heavy paper. Wind the space between the pole pieces with double cotton covered copper wire—No. 16 would be about right if the motor is to be run by battery. The inside diameter of the last layer should be the same as the inside diameter of the pole pieces, or in other words, the wire should not come inside of the circle upon which are the faces of the poles. Make the armature core of discs of sheet-iron about the thickness that is used for stove pipes. The discs are to be 3½ inches in diameter, and punched in the centre to fit tightly on armature shaft, and when there, to be in sufficient number to make a solid cylinder four inches long. They must be secured when the right position is found on the shaft by a spring cotter or pin driven through the shaft at each end of the cylinder.

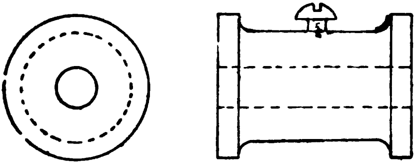


ARMATURE CORE.

Make the shaft of ½-in. machine steel, nine inches long, and put the core $2\frac{7}{8}$ inches from one end of the shaft. Insulate the core by pasting on two thicknesses of heavy brown paper, and also cover the shaft the same way for a distance of 3¾-in. from each end of the core. Divide the circumference of each end of the core into six equal parts exactly opposite each other, and at the division marks saw slits across the corner and insert in each a piece of stiff pasteboard.

The same sized wire is used on the armature as on the fields. Each of the divisions between the pasteboards is to be filled by a separate coil. Begin at the end of your core from which the shaft projects 2⅝ inches and wind on the wire, starting at the right hand side of the division, and take the wire from you on top and bring it back on the under side. Wind half the coil on one side of the armature shaft and the other half on the other, and when you have filled up one division twist a loop in your wire and go on with the next, winding it the same way. Before you begin to wind the next, however, and, indeed, between each winding, place a piece of cotton cloth well shellaced over the wires at each end where they would be touched by the wires of the next coil crossing them.

When you have wound on three coils you will have occupied all the spaces. Give the wire a coat of shellac and cover it all around with cotton cloth and wind on another layer of wire in the same manner over the first; and when you have again filled up the open spaces you will have six coils. Leave a couple of inches hanging from the last coil, and twist it together with the beginning wire of the first coil, and give the whole a thorough shellacing. Wrap two thicknesses of paper around the middle of the armature and on this wind on a dozen turns of fine brass wire to bind the coils down and keep them from flying out when the motor is running at a high rate of speed.



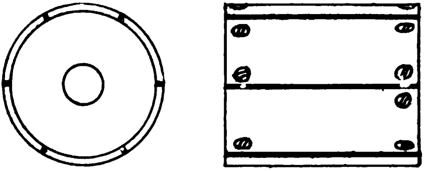
Commutator Spool

FIGURE 2.

For the commutator get a piece of brass or copper tubing 1¼ inches outside diameter, and 1¼ inches long. Turn up a piece of ebonite or box-wood the same length and of the proper diameter to fit snugly in the interior of the tube. Cut this down in the middle as shown in the drawing, leaving enough rim at each end to hold a small wood screw.

Bore ½-in. hole through the centre, and be sure that the hole is exactly in the centre so there is no wobbling when it is placed on the shaft and the shaft revolved.

It might be better to bore the hole first and then put the block on a ½-in. mandrel and to turn it up. Place the piece of tubing over the wooden spool and divide the circumference into six equal parts, and on each division at each end put in a small round head brass wood-screw to hold the tube firmly to the spool. Now, half-way between the adjacent screws at each end make six more marks and on these marks slit the tube from end to end. You will thus have a commutator with six segments, each segment held down by a screw in each end.



Commutator

FIGURE 3.

Let the slits in the copper extend for a short distance into the wood. This will lessen the liability to short circuiting in the commutator from dust and dirt. Before putting on the tube, however, a wood-screw with its point flattened should have been screwed into the middle of the spool to act as a set-screw on the shaft. Then by simply removing one of the commutator segments this screw may be gotten at and the commutator adjusted when the machine is being tried. Place the commutator on the shaft at that end of your armature where the loose ends of the wire are, and push it tight against the winding and screw it down temporarily to the shaft.

You had better give your commutator a lead of about 30° or half a segment for a trial, and leave enough wire loose to make the final adjustment when you start up the motor. In other words, place the slits in the commutator opposite the divisions between the coils and connect the wires at these divisions to the segments just to their left. After putting the commutator on, the armature must be balanced by placing each end of the shaft upon a straight edge which has been carefully leveled. If the armature tends to come to rest in any particular position, a little solder must be added to the binding wire on the top side. This must be done until the armature will stay in any position on the straight edges. A small collar must be put on the armature shaft close to the winding on the pulley end, to protect the winding from abrasion by the bearing when the motor is running.

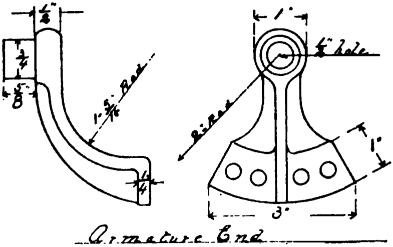


FIGURE 4.

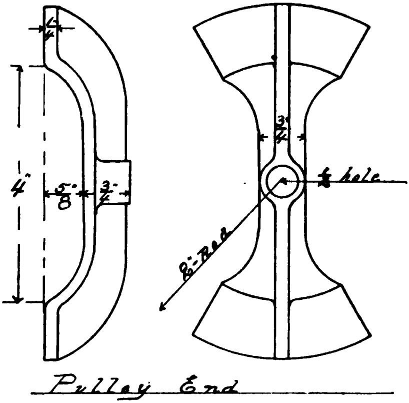


FIGURE 5.

Make the standards of the armature bearings according to the dimensions in the sketches, and from brass.

They are to be screwed to the uncovered space on the fields at the poles.

The brush yoke can be made of hard wood but had best be made of red fibre, and according to the sketch, with a screw with a milled head to clamp it in place when adjusted. The brush holders are also shown and are to be made of brass with a screw in the end which goes through the holes in the end of the brush yoke, and a thumb screw to clamp the brushes. The brushes themselves are made of thin sheet copper $\frac{3}{4}$ of an inch wide, and about two inches long, soldered together at one end and beveled off at an angle of 45° at the other.

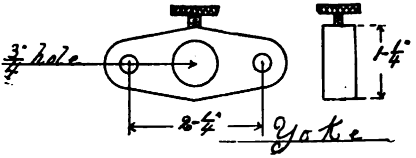


FIGURE 6.

The motor can now be assembled. Screw the fields to a base board of convenient size, and an inch and one-half thick, by means of screws from the under side of the board to the bare iron at one of the pole pieces. Screw on one of the standards and put the armature in place, and screw on the other. Put on the brush yoke and insert the brushes, giving them a good firm bearing on the commutator, and being careful that the ends touch the commutator at diametrically opposite points. A piece of wire should be fastened under the head of each screw which holds the brush holder to the yoke. Connect the wires so they will run in the way shown in the dynamos, and take the ends which come from the fields to binding-posts, suitably placed on the base board.

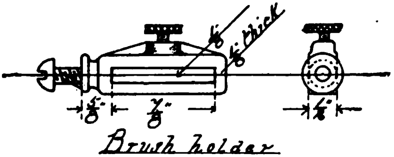


FIGURE 7.

Connect the motor to your battery power, which need not be very large at first, and shift the brush yoke backwards and forwards until there is no sparking at the commutator. If this point of no sparking cannot be reached before the standards interfere with the movements of the brushes, the motor must be stopped and the segment of the commutator over the set-screw lifted and the commutator revolved until it brings this line of commutation where the brushes can reach it.

We have purposely omitted describing a pulley for this machine, preferring to leave it to the judgment and resources of the maker. It must be considerably smaller than the wheel it is going to drive, since a motor to work well should run at as high a rate of speed as possible consistent with the conditions under which it is going to work. A round belt on a small pulley is not very desirable on account of the stiffness of the belt. A thin flat belt would be much better. This could be used by belting from the motor to the shaft on which the fly wheel is. Another method might be employed which the author cannot recommend, from not having ever tried it. This is to put a small wheel, similar to that used on the bobbin winding arrangement with a rubber rim on the motor shaft and

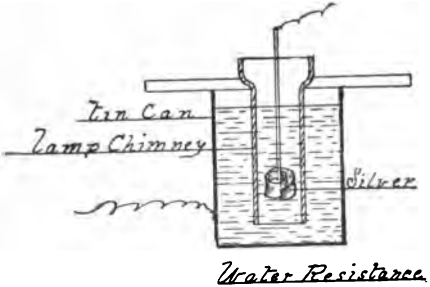


FIGURE 8.

allow this to press against the wheel on top as is done when winding a bobbin.

Some arrangement for regulating the speed of the motor will be necessary. About as cheap a method as any is by means of a water resistance. Procure a long, narrow lamp chimney and a tin can nearly as long and four or five inches in diameter.

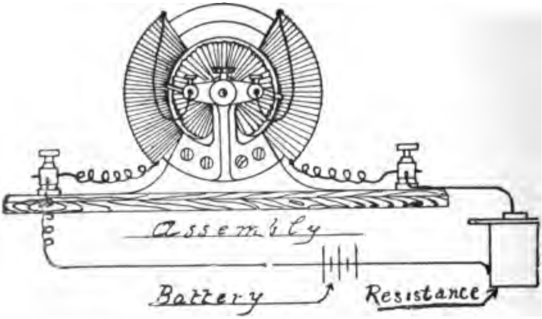


FIGURE 9.

Bore a hole through a piece of board large enough to permit the narrow part of the chimney to pass and so that it will hang by the flare as is shown in the sectional sketch, and let the board rest on the edge of the can. Solder a wire to the tin can—this will form one pole of the resistance. The other pole is a piece of thin silver about an inch wide and two or three long, rolled up in form of a spiral, and soldered to a piece of office wire. Fill the can to within an inch of the top with as pure water as can be had. Connect the resistance in series with the motor and in such a way that the current will go into the wire attached to the silver, through the water, and out by means of the metal can on the wire attached to it.

By raising or lowering the silver in the lamp chimney, the resistance is increased or decreased and can be cut out entirely by dropping the silver until it touches the bottom of the can. If you find the resistance of the water too high for the slowest speed you wish to run your motor at when the silver is drawn clear up, a drop or two of acid will lower the resistance very much. The rising and lowering could be done by foot by attaching the treadle of the machine (which is of course disconnected from the fly wheel) to the wire, soldered to the silver, by means of strings, thus leaving the hands free to hold the work.

CHAPTER VI.

A CHEAPLY CONSTRUCTED ELECTRIC MOTOR.

In designing this motor, the writer has endeavored to construct a machine embodying a comparatively small amount of work with a satisfactory degree of efficiency. The principal feature in the construction is, that the amateur can do all the work that is to be done on the lathe, except the winding of the armature. The pole pieces, *A* and *B*, can be strapped on the face-plate of a 9 swing-lathe, and the junctions *C D* be faced off; at the same time, care being taken not to cut off too much, on account of having too much to bore out of polar space.

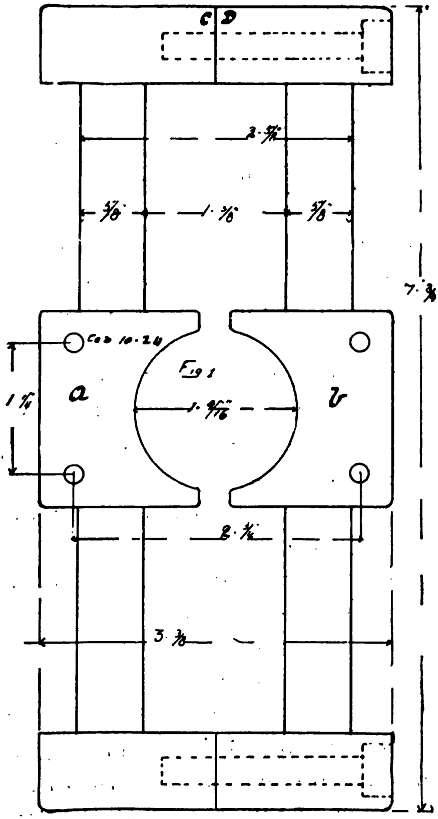
After the junctions *C D* are faced off, the holes can be laid out for the screws to fasten the pole pieces together. The amateur is advised to fasten them together by means of a hand-screw, or a pair of straps and bolts put on over the polar projections and drawn up tight.

Now the operator can drill his tapping-hole through both pieces the right depth. If his counter-bore for the screw-heads has a tit on it any smaller than the body size of his clearance drill for his screws, it will be necessary to use a drill for a short distance, to fit the tit on his counter-bore, and drill his screw-heads out to the required depth, before proceeding further.

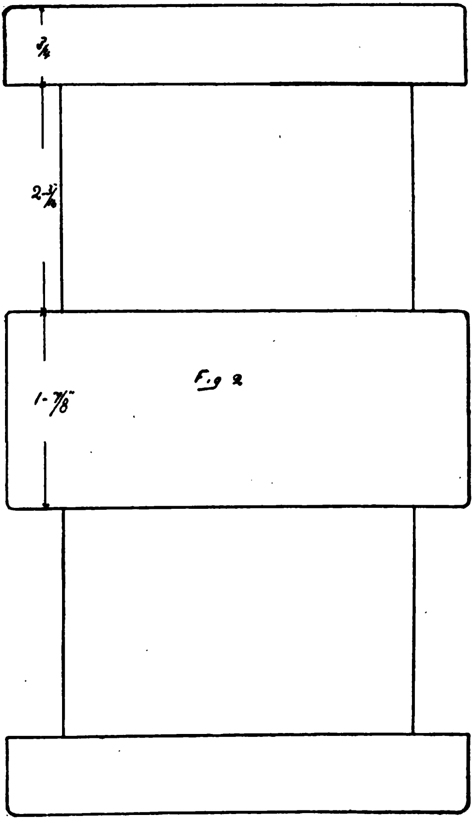
Now that he has this all done, next, he will proceed to drill his clearance holes in *B*, and his tapping-hole in *A;* lastly, put in his screws, and fasten them together. Next, he will proceed to bore out his polar space. But, he is advised to reserve this until after he has his armature wound, as slight irregularities will occur in the winding that might tend to make it scrape or strike against the sides of the polar space, which would necessitate him putting the work in the lathe again, thereby putting him to no end of trouble, if he had the polar space bored out.

But to fasten the work in the lathe, he can put a piece of wood, about one-fourth of an inch thick, back of the work, as he will be able to get his boring-tool all through, without cutting or marring his face-plate; he can fasten it in by bringing a bolt through the slot in the face-plate and up between *A* and *B* beyond the polar projections, and a clamp and nut completes the operation.

Now he can bore out the polar space and face off ends all around, being careful to get all points alike, so that there will be a true surface to clamp



DETAILS OF POLE PEICES.

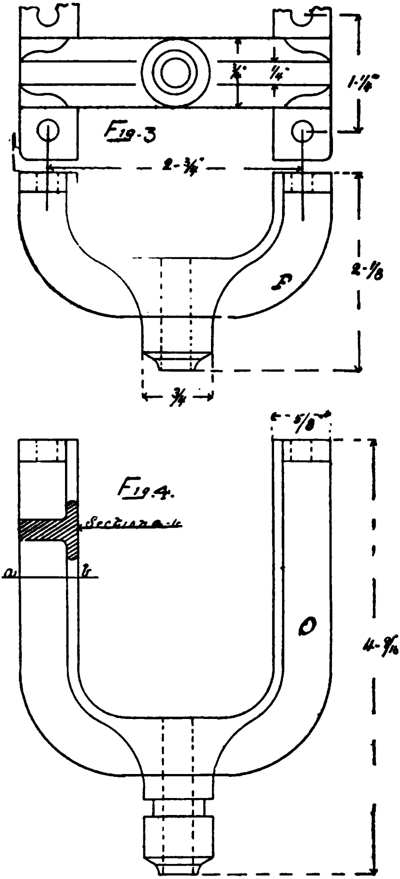


DETAILS OF POLE PIECES.

on the face-plate, when he comes to true up the opposite side, which he need not be so particular about centering, as the polar space is already bored out.

Now, having all this done, he is ready to tackle his armature bearings. The work on those does not amount to much, as all it consists of is in drilling holes to fit the armature shaft, after which they can be driven on an arbor, and the ends of all bearings turned off. Next, drill the holes for attaching the bearings to the pole pieces. This all done, he is now ready to mount the armature, which is a particular part of the work, and wil require some careful handling and nicety of judgment. The first thing to do is, to procure two strips of metal about one-fourth of an inch wide — thickness to be one-half the space allowed between armature and pole pieces. Place them under the armature, and resting on the pole pieces. Now slip on the bearings, and mark off the tapping-holes on polar projections, which have been previously chalked over to facilitate, making a plainer mark, when he is ready to drill the holes and tap them.

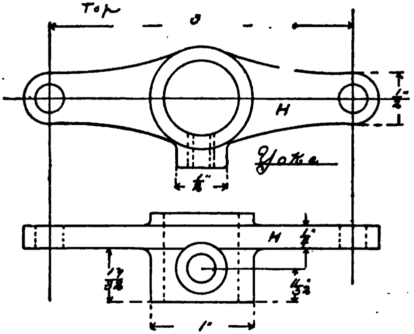
We will now take up the construction of the armature and commutator; right here, it will be as well to say, it is no easy task to construct this part of the machine, and a good deal of patience,



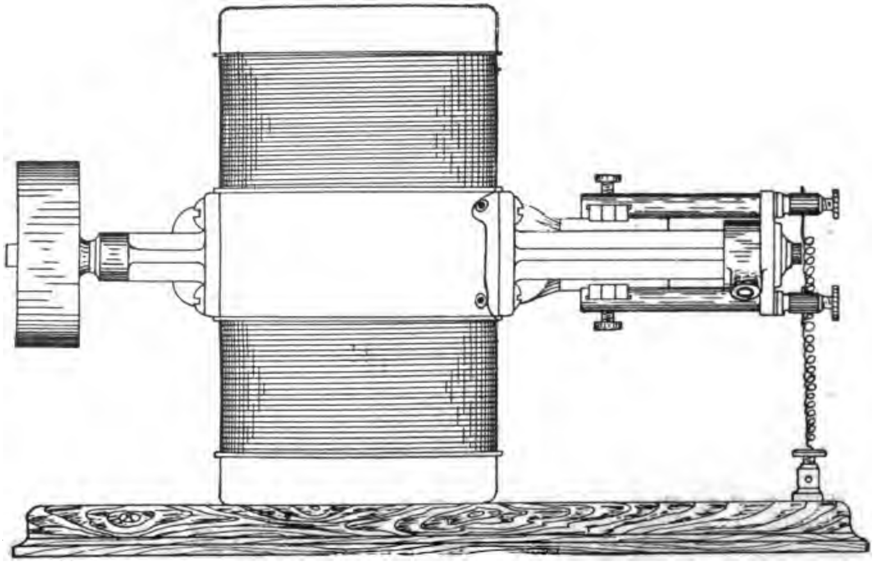
Details of Armature Bearings

good work, and careful handling will have to be exercised.

The first thing to do is, to procure the shaft,—which will be of good machine steel,—drill the centers, put in the lathe, and face up the ends; then take it out of the lathe, and file off the burr that has been left around the center, and slightly ream out with the counter-sink, which should in all cases be the same angle as the lathe centers. The amateur is now ready to turn his shaft, which he will proceed to do according to specifications given.



The armature heads next claim our attention; these can be a casting, but wrought-iron would be much better. Put head *A* in chuck, and drill the hole to a nice fit—for the shaft and commutator as deep as the collar on the shaft is thick; then drive on an arbor (the shorter the better), and finish off outsides; next, put in a milling-machine, and cut 24 slots — $\frac{1}{32}$-in. wide and $\frac{3}{16}$-in. deep — around the edge to hold the pegs, to keep the coils in place while winding. This being done, the head can be taken off the arbor and placed upon the shaft; while the other head is treated in same manner, except that it is not counter bored, but threaded to fit the thread on the shaft, and having three or four small holes drilled in the edge for the use of a spanner wrench in tightening. After placing *A*, insulate the part of the shaft upon which the core is built, — good stout paper being serviceable, and cemented with shellac varnish, after which it must be dried to exude all moisture. Now it is already to receive the punchings, which may be of laminated sheet-iron, having the holes punched a little larger than the shaft, so as all will go on easy. Also have some punchings of tissue-paper, as the core is built up of alternate layers of paper and iron, — first, a disc of paper, then a disc of metal, then paper, etc., until the core is of the required length, which will take some little experimenting to determine just the proper number. Now put on head *B*, and screw up tight; put in the lathe, and take off light cuts till it is brought to required diameter, great care

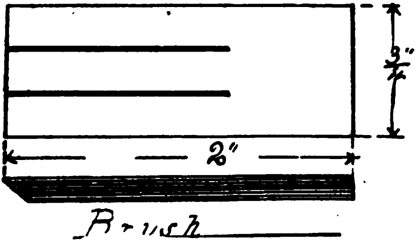


SIDE VIEW OF MOTOR.

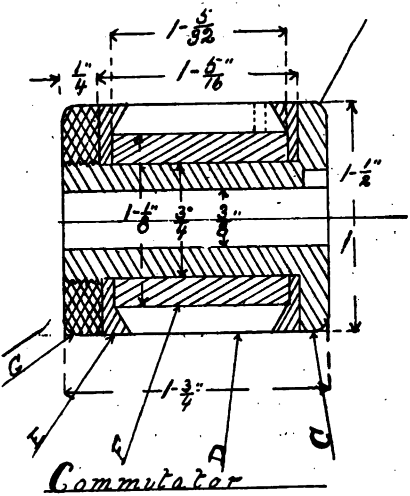
being taken not to spring the shaft. It may be as well to add, that while roughing out the shaft, it is best to leave a finishing cut on the journals, and finish to size only the part whereon the core is built, then if it is sprung any during the operation of turning down the core, there is metal enough left to insure turning up true journals.

The next thing to look for is a commutator. There are several ways of making a commutator, but they all require more or less skill and patience; but we will only discuss the one we have selected for this machine.

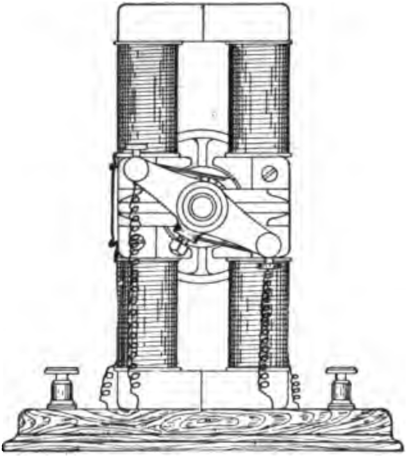
C is a brass sleeve bored to fit the shaft, turned on outside to fit sleeve *F*, and threaded on one end to fit nut *G*. *F* is made of hard rubber or wood, if rubber cannot be obtained. *D* is a segment of commutator. In making the segments, get a casting of pure copper, bore out to fit sleeve *F*, drive on an arbor, and turn off to within $\frac{1}{32}$-in. required diameter, bevel both ends to an angle of 60°; next, put in a milling-machine, and slot in 24 parts, being careful not to cut entirely through, and thereby loosening it from the arbor; you can, after it has been all slotted, separate the segments with a hack-saw. Use $\frac{1}{32}$-in. cutter to slot with. Next, turn two discs of rubber, *E E*, and dish one side of them to the same angle as the commutator bars, then turn up and thread the nut *G*, and the commutator is ready to go together. Begin by putting sleeve *F* on over sleeve *C*, and put on one of the rubber-washers *E*. Now put on all the commutator bars which have previously been filed up, and all the sharp edges and burrs taken off from them, then put on remaining washer *E* and nut *G*, and screw up tight; next procure some strips of mica, as thick as the cutter used in slotting the commutator bars, and insert between all the segments, leaving some little of them extending above the segments, so all can be finished off smooth; now drill the holes, and tap them in the ends of the segment for the screws to fasten the lead-wires to, upon the completion of which the armature is ready to be wound. Drive thin pegs in all the slots in the armature heads, which pegs need be about $\frac{3}{16}$-in. wide, and $\frac{5}{16}$-in. from the metal. The winding for this armature consists



of No. 20 double-covered cotton-wire, 12 coils, 2 layers in each coil, and 7 turns in each layer. Now begin by putting a dog on the end of the shaft opposite the commutator, and putting it in the lathe; have the wire conveniently arranged so as

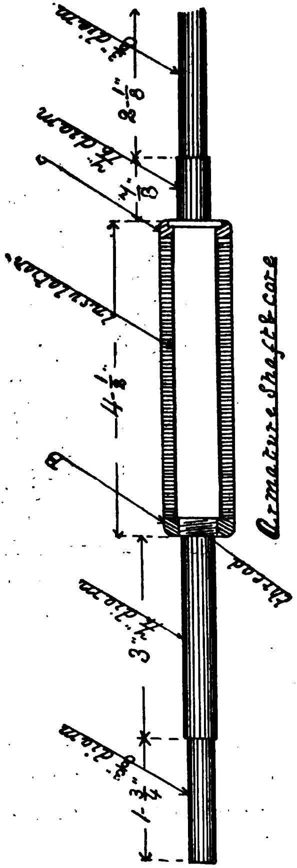


to admit of its reeling off freely; now twist one end of the wire around the shaft at the commutator end, so as to hold it in place while the first layer of 7 convolutions is laid on; place them all on one side of the shaft, and between the two pegs diametrically opposite each other. After winding the inner layer, the winding is continued, and another coil of 7 convolutions placed upon the first, and all the wires carried over to the opposite side of the shaft. When the second layer is completed, the wire is cut, and the ends twisted temporarily together. Before twisting the ends, however, the inner terminal should be coated with the varnish, so as no trouble will be experienced in determining which is the inner and which is the outer terminal; each coil is put on the same all the way round, care being taken, however, all through the operation, not to get the insulation scraped off from the wires. The winding being now completed, the next in order is to fasten the winding, so as to avoid the destructive effects of the centrifugal force. The best way to do this is, to put on 3 or 4 bands, consisting of No. 28 or 30 brass-wire, 10 or 12 convolutions each, and placed equidistant the length of the armature; to hold the wires together in the bands, solder them in several places. A band of rubber-tape should be interposed betwen the wire of the armature and that of the bands. The next operation is to connect the terminals to the commutator bars: to begin, take the terminals of one coil and straighten out parallel with the sides of the armature, and clean off the insulation for a short distance on the end; loosen the screws in the segments, bring the outer terminal of its coil down, and connect with one of the segments and the inner terminal of the same coil with the segment adjoining; the outer terminal of the second coil is connected with the inner terminal of the first, while the inner terminal of the second coil is connected with the next or third segment, and so on all around till all is connected.



END VIEW OF MOTOR.

The yoke, brushholder, and brushes come next; a good yoke can be made out of leatheroid, thereby avoiding the necessity of insulating the studs. A careful inspection of the details of those parts will furnish all information necessary for their construction.


1-3/4"
3/8" diam
3"
1/2" diam
thread
B
4-1/8"
Insulation.
C
7/8"
7/16" diam
2-1/8"
3/8" diam.
Armature Shaft & core

The writer has concluded by this time, that enough attention has been bestowed upon the methods of starting and finishing, and the manipulation of tools, etc., to insure any ordinary intelligent amateur to turn out a successful job — the brushes, though, require a brief notice.

Make of hard, thin copper, split in two places, and, for convenience in handling, they may be soldered together at the stud end; in winding the fields, begin at the top and wind one section full, wind the wire around two small pins, shown in assembled view, and carry it to and fill up next section, fasten and cut off — this wire will be at the bottom of the field; — wind opposite field same way. Now take the two terminals of the top, which will be the inner terminals, and carry them down through the board; or, if preferred, they can be brought directly down in neat coils and connected to brushes, while the lower terminals are carried through the board and fastened to the binding-posts. The machine is now ready to start. A good battery to run can be made from one-half dozen pint jars of bichromate cells; and the power this machine will give out will astonish you.

CHAPTER VII.

HOW TO MAKE AN ELECTRIC BATTERY FOR RUNNING ELECTRIC MOTORS.

To generate a current of electricity from a dynamo, one must apply to it mechanical energy. This can be obtained by hand-power, steam-power, or water-power. The reader may use whichever is most convenient. Where water-power can be obtained, it will be found the cheapest, and a good water-wheel is a thing very cheaply and easily constructed.

A motor can be run either from a current obtained from a dynamo or a good Voltaic battery.

The storage-cell will be found the best and cheapest in the end, where one has means of charging it.

This cell can also be charged either from a dynamo or a number of primary batteries. Next to the storage-battery, a good bichromate plunge-battery will probably give good results, and can easily be constructed in the following manner: —

A Plunge-Battery. — The carbons for the battery may be either bought from some dealer in electrical supplies or sawed from "gas-carbon" — the carbon deposit taken from the sides of gas retorts. The dimensions should be 6 x 10 x $\frac{1}{4}$-in.; and, if you make them as indicated above, and find difficulty in getting pieces of that length and six inches broad, you can take two narrower pieces, and put them side by side, to make up the six inches.

If it is possible to do so, you should plate one end of each carbon with copper for about half an inch. This is a very simple operation, where you can command the necessary current, it being only necessary to clamp the carbon-plate to one of your wires, and dip it the required depth in a solution of copper-sulphate, in which is a copper-plate connected to the other wire, and pass the current through the solution from the copper to the carbon.

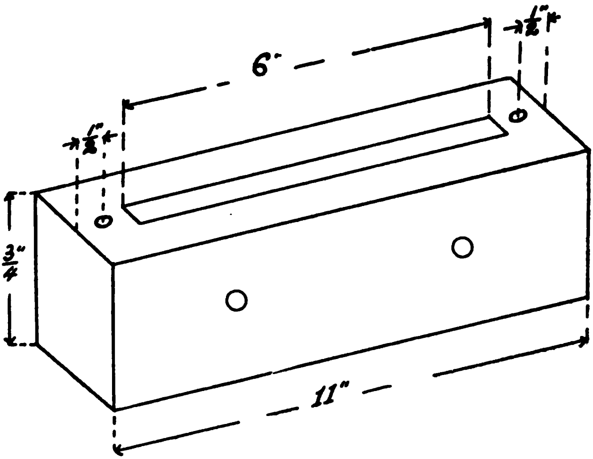
There should be a pressure of about four volts around the plating-bath. If the copper deposits in a sandy form, or has a brick-red color, there is too much current. When the current is right, the copper will have a fine flesh tint.

Wash the plated ends when you take them from the bath. You will need 21 such plates.

You will also need 14 zinc-plates, 6 x 10 x $\frac{1}{8}$-in.

To support the plates in the frame, make 35 wooden pieces, as shown in the sketch, from oak.

Fig 1



Fourteen are of course for the zincs, and the slot in the middle is made ⅛-in. wide, and for the other 21, ¼-in. wide.

The holes at the ends are for any convenient size of iron-wire, say 3/32-in. or ⅛-in., which is to fit in them loosely.

These sticks must all be thoroughly soaked in hot paraffine. Near the top of each zinc-plate, ⅜-in. from the end, drill two holes for iron-wire pins, two inches from each other and from the sides of the plate; and at the top of the carbon-plates drill three similar holes, 1½-in. from each other and from the sides of the plate. Drill holes in the sides of the supporting-sticks corresponding to those in the plates; and by putting the ends of the plates in the slots, and iron-wire pins through the holes, you have your plates suspended

Make the battery-box of 1-in. well-seasoned pine. The box inside is 27½-in. long, 7 in. wide, and 9½-in. deep. The length of the box is divided into seven compartments by ½-in. partitions. From the inside of the end of the box to the centre of the first partition is 3¾-in., and of course it is the same at the other end. The distance between the centres of the partitions is uniformly 4 in., giving seven compartments 7 x 9½ x 3½-in. inside.

Make all joints as tight as possible, and cover the inside of the cells with the acid-proof cement, whose composition is given:

Make a solution of india-rubber in twice its weight of raw linseed-oil, heat and mix with an equal weight of pipe-clay. This cement never hardens completely, but can be worked over at almost any time.

Another cement sometimes employed is made by mixing quick-lime and linseed-oil together to form a stiff paste, which is spread over the object you wish to protect.

You will have to screw a broad board to the bottom of the box, as it is so high it needs a large base.

To each end of box, screw a standard, as shown in the sketch, with a notch in the top to hold a piece of $\frac{5}{8}$-in. round iron, the bottom of the notch to be $11\frac{1}{2}$-in. from the top of the box.

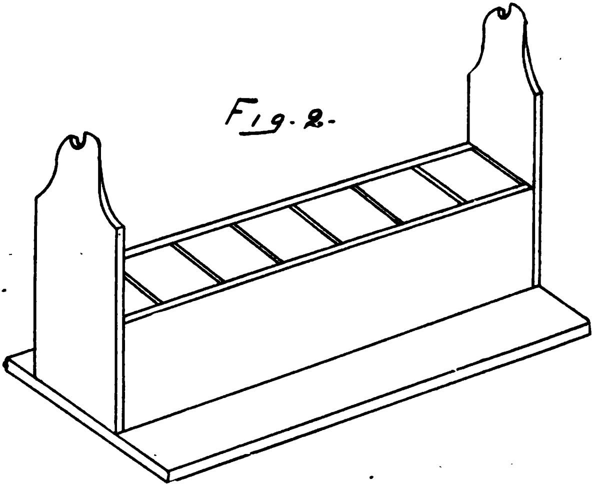


Fig. 2.

Make the notches about half an inch to one side of the centre line, so that the plates will hang centrally in the cells when the chain is wound over the side of the shaft.

The frame for holding the plates is made (as shown on next page) from 1 x 1½-in. oak.

The pieces are fastened together at the ends by carriage-bolts, after having been thoroughly paraffined. A ¼-in. iron-rod passes through the middle of each end-piece, and has an eye turned in one end, and the other rivetted over a washer on the under-side of the stick.

The positions of the iron-pins in the side sticks can best be determined by placing the frame in position on the top of the box, and arranging the sticks, to which the plates are attached in groups of five, packed closely together on top of it. Each group must be arranged so that the plates, when suspended from it, will hang in the middle of the cell beneath.

Then mark the positions of the holes in the ends of the suspending-sticks on the side-sticks of the frame, and drive in your pins at this point.

Make the shaft by which you raise and lower the plates of ⅝-in. iron, and have one end upset by a blacksmith, so that it makes a disc an inch and a half in diameter, and ⅛-in. thick. File the edge into saw-teeth, about a quarter of an inch apart, and this will make you a ratchet-wheel, to keep the plates at any desired height. The pawl can be filed out of ⅛-in. iron, and drilled for a screw. The

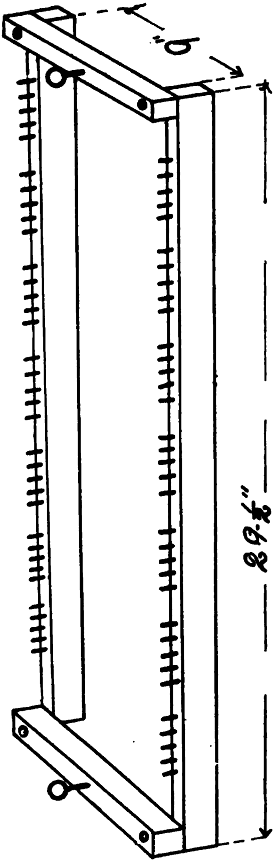


FIGURE 3.

other end of the shaft can then be bent so as to form a crank, the distance between the ratchet-wheel and the bend being the outside measurement from standard to standard, or 31½-in.

The plate-frame is to be hung by a chain from the shaft. There is a flat chain made which is well adapted to this work, as it takes up less room when wound on the shaft.

We are now ready to set up the battery.

Amalgamate the zincs by dipping them in some dilute sulphuric acid, to clean them, and then rubbing a little mercury over the surface of each until it presents an even, bright appearance.

The amalgamation need not be carried nearer than an inch of the top of the plates.

Put the plates, both carbon and zinc, in the suspension-sticks, and fasten them there by pins. Five plates go in each cell — three carbons and two zincs. The carbons are placed on the outside and in the middle, and the zincs in the remaining two spaces. Hang them in this order in the frame.

Solder a wire to the top of each plate — the copper on the carbon enabling you to do this. Supposing you look down on the tops of the plates, fasten the wires on the carbons to the right-hand corner, and those on the zincs to the left-hand corner. Reverse this in the next cell, and so on, thus: (See illustration on next page.)

The wires from the end cells are to be connected to suitable binding-posts on the frame.

If copper-plating the tops of the carbons is an impossibility, a piece of sheet-copper can be wedged between the carbon and the stick holding it, and the wire soldered to that; but the plated-tops are much to be preferred.

The plated-ends ought to be paraffined about a quarter of an inch below the plating, to keep the creeping salts from destroying the contact with the copper.

To three pints of cold water add five fluid ounces of sulphuric acid. When this becomes cold add six ounces (or as much as the solution will dissolve) of finely pulverized bichromate of potash. Mix well.

Lower the plates into the cells, and pour enough of this solution in each to fill within an inch of the top, and your battery is ready for business.

Don't leave the plates standing in the fluid when not in use, as they will rapidly wear out. By raising and lowering them, you can vary the strength of your current to any desired degree within the limits of the capacity of the battery.

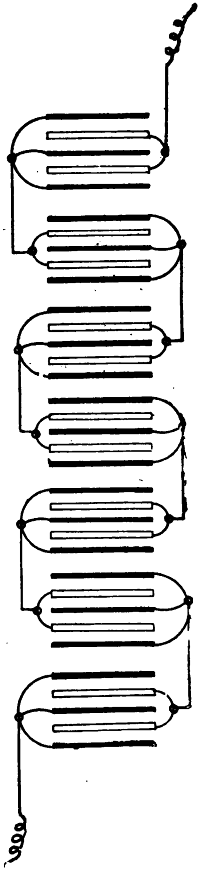
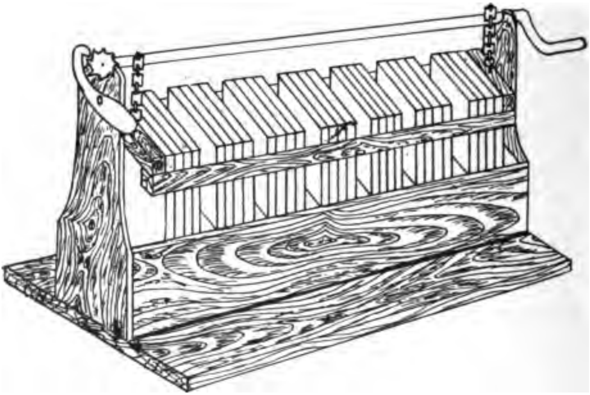


diagram of connections

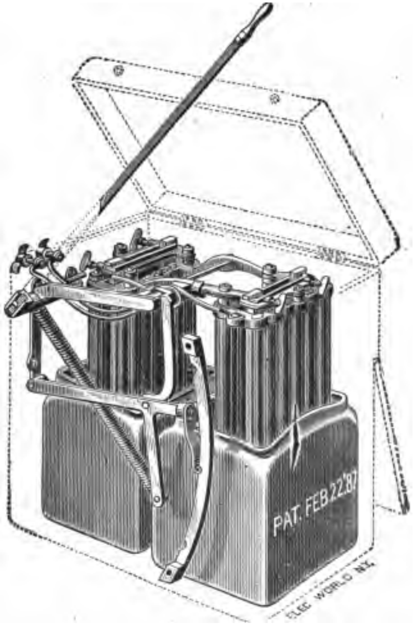
FIGURE 4.

Fig 5



A very good battery to be used for running small motors, has lately been put on to the market by the C. & C. Electric Motor Company. The one shown in the engraving has two cells, and was designed expressly for use with the "C. & C." Electric Motor. Its character and capacity are as follows: Size, 8 x 12 x 12 inches; electro-motive force, 3.9 volts; resistance, .06 to .15 ohms.

Gives 8 to 10 ampères with motor, when running average sewing-machine at full speed. Gives 8½ ampères with motor running at 1,200 turns per minute, and gives 30 ampères on short circuit. That is to say, one charge will run your sewing-machine for four hours and upwards.



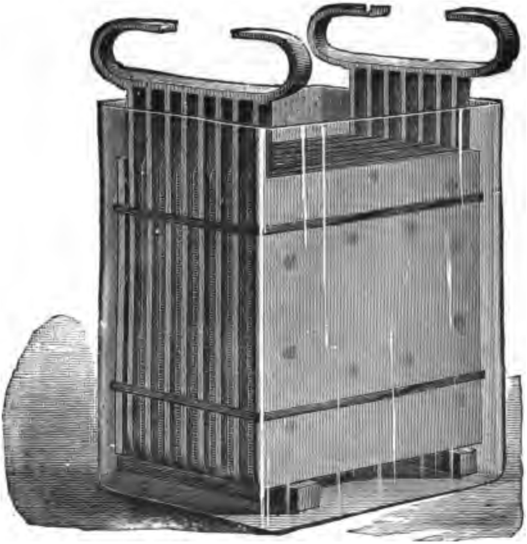
C. & C. BATTERY.

Life of one charge, 40 ampère hours.

The battery consists of two cells, in series, the electrodes of which are mounted on a lever and balanced by a spring, so that they can be conveniently raised and lowered by the lever on the outside of the box, which remains at any point at which it is placed, giving any desired depth of immersion; the depth of immersion regulating perfectly the current supplied, and, consequently, the power of the motor and the speed of the sewing-machine.

For convenience in starting or stopping your motor, it would be well to place a switch in the circuit between the battery and motor.

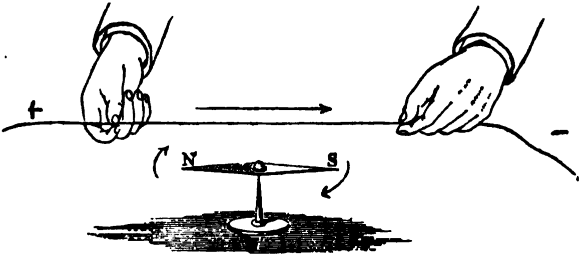
This will be found a great convenience, especially where the storage-battery is used. When a bichromate plunge-battery is used, it will not make so much difference, as it is necessary to lift your zincs out of the solution when not in use, as the solution will act on the zincs continually when they are immersed, whether in use or not. Never try to drive a dynamo from a motor actuated by a battery, for the best motor wastes at least 10 per cent. of the energy put into it in the mere act of conversion, while the dynamo itself will waste at least



STORAGE BATTERY CELL.

5 per cent. in reconverting the motion into electricity. A much better light could be obtained from the battery direct.

If you wish to run a motor more than four or five hours, you must use the storage-cell, as the bichromate-cell must be taken to pieces, cleaned, and recharged in that time, before it will be fit to use again.



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